Crystal Physics

Prof. **Kazuo Nakajima**（1998.10～）

【Staff Members】

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【Research Activities】

1) Studies on the crystals for solar cells with high conversion efficiency

We have fabricated multicrystalline SiGe solar cells with microscopic compositional distribution and proved, for the first time, that SiGe bulk multicrystals with an average Ge composition of 5% gave 1.3 times higher conversion efficiency than Si bulk multicrystals did. We studied the cause of this high efficiency, and concluded that Ge-rich regions in the crystals refracted light and thus elongated effective optical pass increased the absorption coefficient of the cells.

To elucidate key parameters necessary for the increase in the quality of Si bulk multicrystals, we developed an in-situ observation system available up to 1500° C, and succeeded in observing melt growth process of Si crystals in-situ for the first time. Using this system, we found that a dendrite growth mechanism of Si crystals could be applied to control the crystallographic orientations of Si bulk multicrystals. Our new findings in the growth of high quality Si bulk multicrystals are highly evaluated by NEDO and other companies as core technologies necessary for future studies on solar cells.

We found that Si crystal wafers with various three-dimensional shapes can be prepared using plastic deformation under certain ranges of temperature, thickness and pressing overweight. Since these Si crystal wafers with various shapes have enough quality for preparing solar cells and X-ray condensing lenses, this process can be a promising technique to prepare a new high-efficiency solar cell system with the concave Si crystal mirror solar cells. The crystal lenses are also very useful for preparation three-dimensional X-ray crystal lens.

2) Growth of multi-component bulk substrate crystals with uniform composition and studies on hetero-epitaxial structure with controlled strain

We found that a <110> direction is a preferential orientation for the growth of InGaAs crystals. We used a (110) face of a GaAs seed crystal and succeeded in growing a InGaAs single crystal even when InAs composition was close to 25%. This growth technique gave big progress in the growth of InGaAs single bulk crystal.

3) Studies on the crystal growth of organic materials

We developed a novel in-situ observation technique by which movement of individual protein molecules in the vicinity of a solution-crystal interface can be tracked real-time. This technique can be a promising tool for studying mechanisms of protein crystallization.

1. Pan W., Fujiwara K., Usami N., Ujihara T., Nakajima K., and Shimokawa R.
Ge composition dependence of properties of solar cells based on multicrystalline SiGe with microscopic compositional distribution
J. Appl. Phys., 96 (2004), 1238-1241.

2. Fujiwara K., Obinata Y., Ujihara T., Usami N., Sazaki G., and Nakajima K.
Grain growth behaviors of polycrystalline silicon during melt growth processes
J. Cryst. Growth, 266 (2004), 441-448.

3. Nakajima K., Fujiwara K., and Pan W.
Wave-shaped Si crystal wafers obtained by plastic deformation and preparation of their solar cells
Appl. Phys. Lett., 85 (2004), 5896-5898.

4. Azuma Y., Nishijima Y., Nakajima K., Usami N., Fujiwara K., and Ujihrara T.
Successful growth of an $In_xGa_{1-x}As$ ($x>0.18$) single bulk crystal directly on a GaAs seed crystal with preferential orientation
Jpn. J. Appl. Phys. 43 (2004),L907-L909.

5. Sazaki G., Matsui T., Tsukamoto K., Usami N., Ujihara T., Fujiwara K., and Nakajima K.
In-situ observation of elementary growth steps on the surface of protein crystals by laser confocal microscopy
J. Cryst. Growth, 262 (2004), 536-542

【Plan】

Our main areas of research include (but are not limited to)

(1) Development of novel photovoltaic materials for high-efficiency solar cells

We attempt to develop a novel crystal growth technique to realize multicrystalline Si ingots with artificially controlled orientations, grain boundary characters, and grain sizes, which are believed to surpass single-crystalline Si in terms of crystal quality. This pioneering study will lead the research and development of practical solar cells. The mechanism of the improved conversion efficiency of the solar cells based on SiGe multicrystals with microscopic compositional distribution will be clarified at a fundamental level, which will play an important role to industrialize thin film crystal solar cells for the next generation. Furthermore, record conversion efficiency will be pursued based on a novel solar cell system using Si concave mirror solar cells.

(2) Development of multicomponent semiconductor bulk crystals with uniform composition and their application to novel semiconductor substrates

Novel crystal growth technique to realize multicomponent semiconductor bulk crystals with uniform composition will be established to widen the choice of lattice-constants and band gaps of semiconductor substrates for strain-controlled epitaxial growth of heterostructures, which leads to the development of new functional materials. The validity of this concept will be demonstrated by a prototype high-mobility devices based on strain-controlled SiGe heterostructures grown on homemade SiGe substrates.

(3) Fundamental studies on epitaxial growth mechanisms of organic semiconductor thin film crystals

We will clarify the key mechanisms to control the alignment of organic molecules, which will be utilized to develop a novel epitaxial growth technique to realize "single-crystalline" organic semicondoctor thin films.
Intensive research will be devoted to next five years to accomplish the above targets.